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FINAL TECHNICAL REPORT FOR
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Topography-Induced Variation in Benthic Boundary Layer Particle Dynamics & Fauna

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Objectives

The long term objective of this research was to identify the physical and biological mechanisms that regulate the structure of infaunal communities on Pacific seamounts. Of particular interest were the interrelationships of hydrodynamic regime, organic input, sediment properties, oxygen availability, and their influence on infaunal communties inhabiting seamounts. Studies involved comparisons of sediments and infauna in naturally-varying and experimentally-manipulated settings on Volcano 7 off Mexico and the summit plain of Fieberling Guyot. Seamounts serve as excellent models for evaluating the response of benthic assemblages to physical processes in the open ocean.

Approach

The submersible ALVIN was used to study sediments and animals at sites on the flanks of Volcano 7, which intercepts the eastern tropical Pacific oxygen minimum zone (OMZ) in 1988 and on the summit plain of Fieberling Guyot during 3 cruises in 1990 and 1991. Two sites were examined on Fieberling Guyot; Sea Pen Rim (SPR, 635 m) on the NW rim of the summit plain and White Sand Swale (WSS, 580 m), located further towards the plain interior. SPR has a relatively stable substratum with sediments consisting of basaltic gravel and armored fines while WSS's foraminiferal sands provide a continually shifting substrate. During each cruise, cores were taken to describe the sediments, organic content, microbes and infauna occurring naturally at each site. Fences were placed at each site to reduce flow for 6-wk and 6.5-mo intervals, and weirs were placed to intensify flow for 6 wk at WSS only. Colonization trays containing defaunated sediments were deployed for 6-wk and 6.5-mo periods to compare faunal mobilities and recolonization potential at the two sites. Treatments were examined for microbial abundance, infaunal abundance, composition, diversity, vertical distribution and lifestyles. As part of this project L. Leithold (NCSU) used bottom stress estimates based on BASS measurements (courtesy of T. Gross, Skidaway) and moored current meter data (courtesy of C. Eriksen, U. of Washington) in combination with sedimentologic data to evaluate the frequency, intensity and mechanisms of sediment transport occurring at each study site. These data are integrated with faunal studies to evaluate hydrodynamic influences on the Fieberling benthic fauna.

Results

FIEBERLING GUYOT

Preliminary analyses indicate significant differences in sediment characteristics and mobility at Sea Pen Rim (SPR) and White Sand Swale (WSS). At SPR surface sediments are spatially variable, with modal grain sizes ranging from granule to fine sand size. Samples from SPR typically have mean and modal size of 1 to 0 phi (0.5 to 1 mm) and are poorly sorted (Figure 1). The modal size class is composed of basalt fragments.

Comparison of critical shear stress (2.9 dyne/cm^2) for these particles to BASS measurements of bottom stress during 8 da in Dec. 1990 indicate that these grains were not mobilized at any time. Finer size fractions (generally < 10% mud) may have been mobilized under the conditions recorded, but armoring of the seabed by coarser, basaltic grains would reduce the amount of this sediment in transport. White Sand Swale sediments are fairly uniform. They are characterized by fine to medium foraminiferal sands with mean grain sizes of about 2 phi (.250 mm), and are moderately well sorted (Figure 1). Comparison of critical shear stress for the mean grain size (1.08 dyne/cm^2) to a 5 day BASS record from Oct. 1990 indicates that sediments should be transported on a daily basis (during 10-20% of the total record). This estimation is consistent with the observation of fresh, sharply defined ripples at the site during each cruise.

Organic C content of sediments was very low at both sites in Dec. 90 (0.16-0.21%). Microbial counts did not differ between sites during any cruise (1-4 x10^8/ml). At WSS after 6 wk, surface counts were enhanced inside flow reduction treatments (fences) and diminished inside flow-intensification treatments (weirs). After 6.5 mo microbial abundance in colonization trays did not differ from natural sediments at SPR, but was reduced at WSS.

In Dec. 1990 natural sediments at SPR and WSS exhibited similar total macrofaunal densities (1800-2000 m^{-2}), high diversity and low dominance. Despite these superficial similarities, infaunal composition varied considerably (Figure 2). WSS was inhabited primarily by burrowing forms, including aplacophorans, sipunculans, polychaetes and turbellarians that often resided fairly deep in sediments. In contrast, the SPR fauna was concentrated near the sediment-water interface, and was dominated by suface-feeding taxa, including ampharetid polychaetes, ophiuroids, crinoids, sponges and peracarid crustaceans. Colonization of defaunated trays after 6 wk was higher at WSS than SPR, but well below densities found in background sediments. Trays at both sites were colonized largely by hessionid polychaetes, bivalves and aplacophorans (Figure 3). Weirs led to reduced densities of macrofauna after 6 wk, the majority of which inhabited deeper sediments > 2 cm. Fences deployed for 6 wk did not influence total density of macrofauna at either site, but led to elevated or reduced densities of specific taxa.

Differences in sediment mobility at rim and interior study sites appear to have a profound influence on faunal composition, vertical distribution and lifestyles (Figure 2), without affecting gross features of macrofaunal communities such as density or diversity. In a coarse-grained setting subject to regular bedload transport, we observed (a) prevalence of vermiform, burrowing taxa, (b) deeper infaunal distributions within sediments, (c) greater faunal mobilities and colonization potential, and (d) a high proportion of predators. In a coarse-grained sediment having greater stability due to higher sediment density and armoring effects, the fauna exhibited (a) prevalence of epifaunal or tube-dwelling taxa, (b) shallower infaunal distributions within sediments, (c) increased proportion of sessile taxa, (d) reduced colonization ability, and (e) increased proportion of filter feeders.

VOLCANO 7:

Studies of Volcano 7 macrofaunal assemblages indicate that oxygen exerts primary control of abundance, composition and diversity of bathyal fauna in the eastern tropical Pacific. Microbial and meiofaunal communities were found to exhibit greater tolerance to low oxygen conditions (< 0.1 ml l^{-1}) than macro- and megafaunal communities, and were better able to utilize labile organic matter under these conditions. Very abundant, but species poor assemblages of mega and macrofauna were present at the OMZ boundary (0.1-0.3 ml l^{-1}). Among macrofauna, tube-building, shallow burrowing and surface feeding forms dominated in the low oxygen zones.

The Volcano 7 OMZ boundary exhibits macrofaunal patterns resembling those typically observed along shallow-water gradients of organic pollution. Volcano 7 findings lend support to the concepts that (1) OMZ boundaries are regions of enhanced biological activity, (2) seamounts interacting with OMZs can provide isolated settings suitable to promote allopatric speciation, and (3) fauna inhabiting seabeds that intersect OMZs can shed light on the use of biogenic structures to reconstruct oxygenation histories of ancient marine basins.

Conclusions

Preliminary results suggest that seamount-generated bottom currents producing sediment instability in coarse-grained sediments lead to assemblages of vermiform, burrowing taxa that feed and live well below the sediment-water interface but are suprisingly good colonizers. When armoring prevents strong currents from inducing sediment transport, the fauna is dominated by surface-feeding taxa that reside near the sediment-water interface, and exhibit poor colonization potential. In this setting hydrodynamic effects on soft-bottom assemblages are mediated by sediment transport.

Studies on Volcano 7 and Fieberling Guyot, as well as other Pacific seamounts suggest a heirarchy of physico-chemical factors controlling infaunal community composition on seamounts, and in the deep-sea in general. Oxygen availability, organic matter inputs to the seafloor, and sediment stability take precedence over particle size or water depth in determining the structure of soft-bottom benthic communities. These investigations provide evidence that physical processes interacting with topography generate considerable biological heterogeneity on seamounts, and may do so in other settings (e.g., canyons, banks, shelf-slope breaks) as well.

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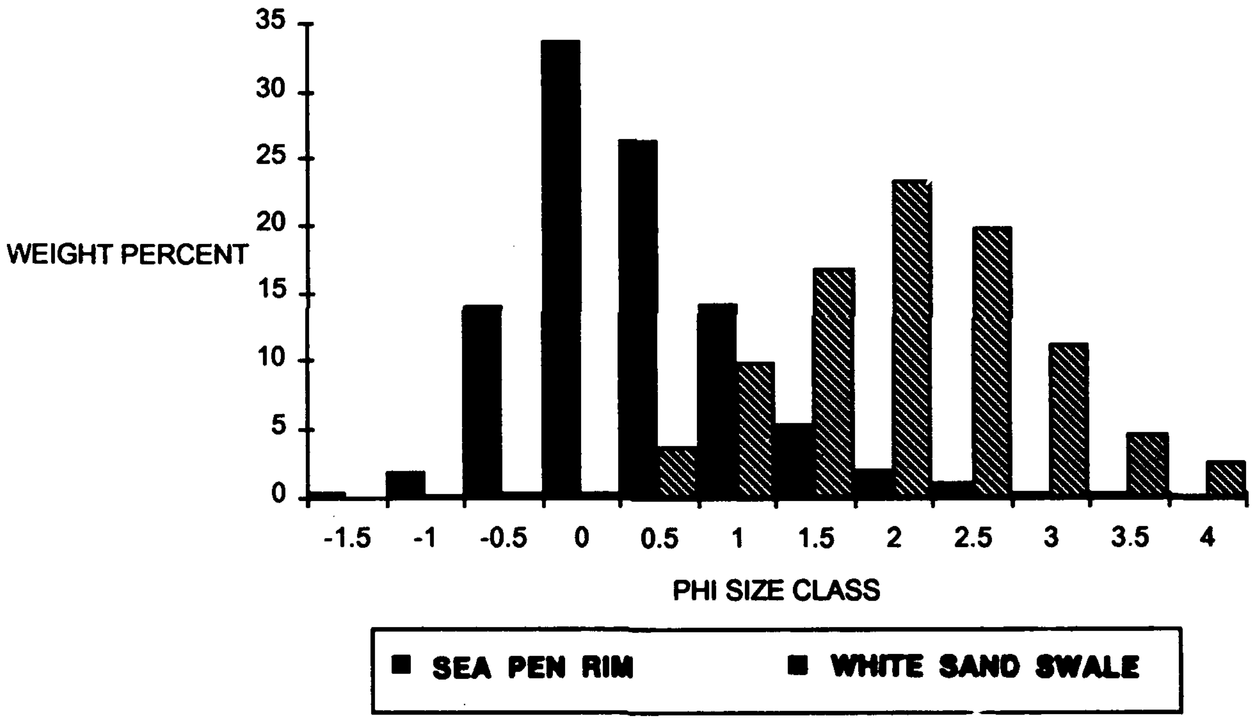

Figure 1. Typical size frequency histograms for sediments from Sea Pen Rim (SPR, 635 m) on the NW rim of the Fieberling Guyot summit plain and from White Sand Swale (WSS, 580 m) located in the interior of the summit plain. SPR sediments are dominated by basalt fragments. WSS sediments are primarily foraminiferan tests.

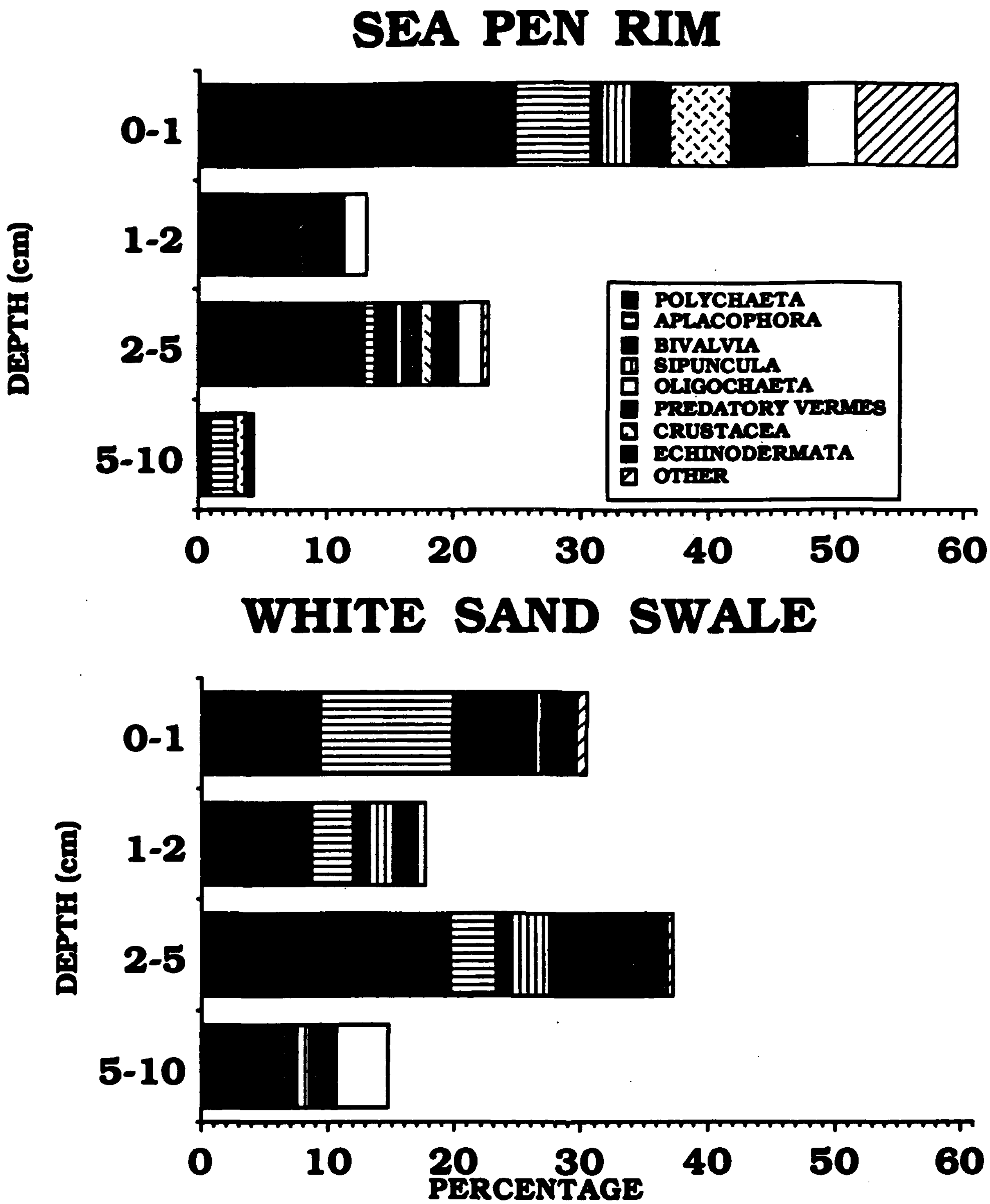

Figure 2. The taxonomic composition and vertical distribution of macrofauna (> 0.3 mm) are shown for two sites on the summit plain of Fieberling Guyot. Percent of total animals collected at each site are shown for each sediment fraction. Sea Pen Rim (635 m), located on the NW rim, has stable sediments in which basalt gravel and sand armor clays. White Sand Swale (580 m) in the interior has shifting foraminiferal sands subject to daily bedload transport. Sediment mobilities are hypothesized to account for differences between sites in species composition, vertical distributions within the sediment column, and lifestyles.

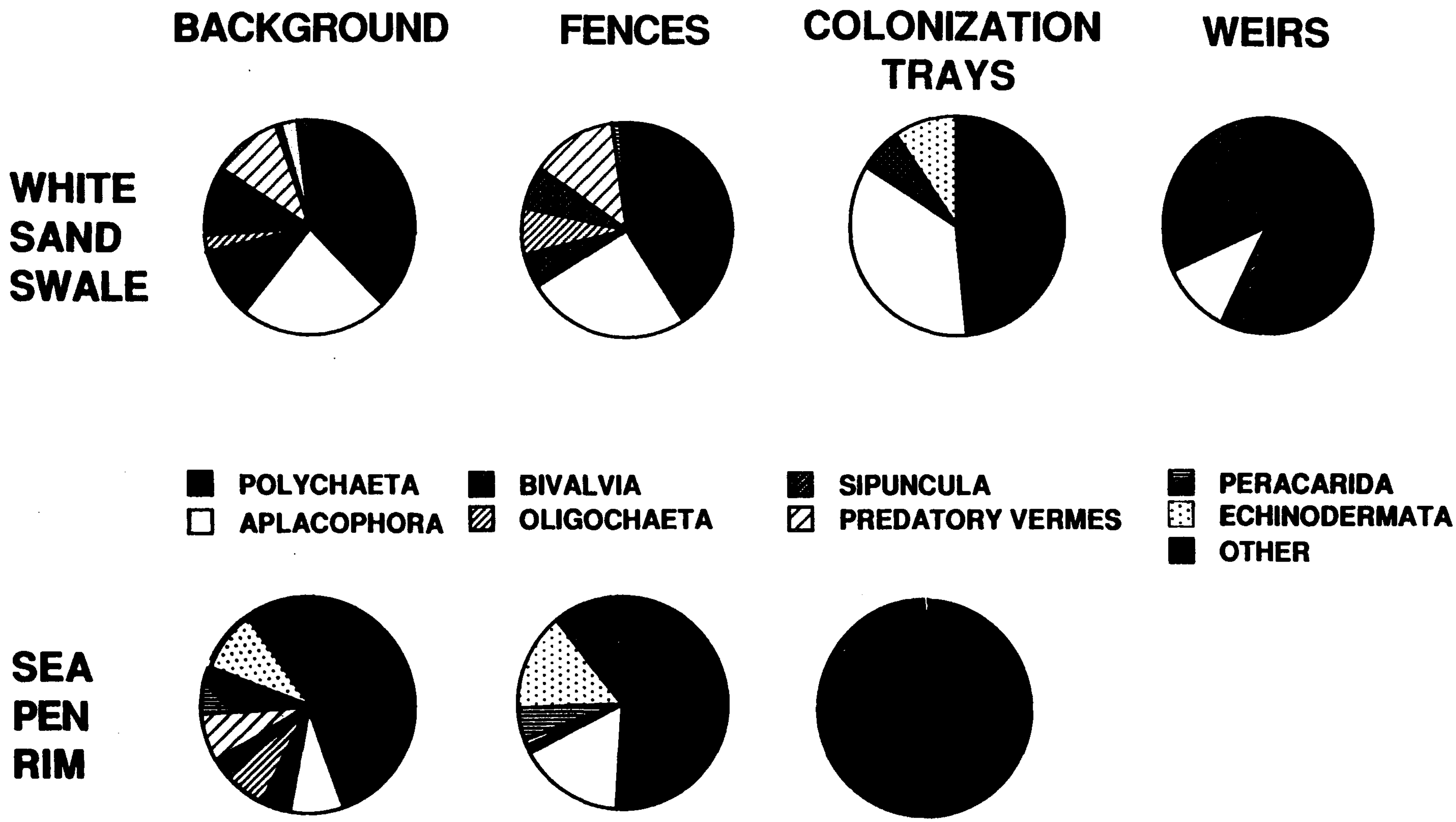

Figure 3. Taxonomic composition of macrofauna (> 300 μm) at Sea Pen Rim (635 m) and White Sand Swale (580 m) on Fieberling Guyot in December 1990. Samples are from natural sediments (background) and from 6-wk deployments of reduced-flow treatments (fences), intensifi treatments (weirs), and colonization trays containing defaunated sediment.